White Paper

How Design Optimization Can Help Vault Your Product Ahead of Competitors'

By Gilles Eggenspieler
Lead Product Manager
ANSYS, Inc.

Simulation offers the potential to improve the performance of nearly any product or process by predicting its behavior prior to building a prototype, providing much more diagnostic information than physical testing. But conventional simulation predicts the performance of only a single design point at a time. In the real world, there are usually many design parameters whose potential combinations result in an often incalculable number of design points. How do you quickly determine the design point that delivers the best combination of performance, cost, weight, size and other design parameters that make the difference between success and failure?

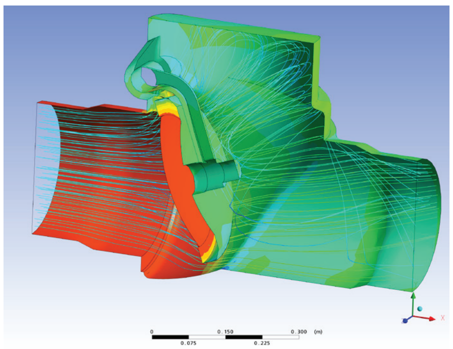
Design exploration addresses this challenge. It automatically simulates the minimum number of design points needed to map out the complete design space, then confidently identifies the design that goes well beyond meeting specifications — one that provides the highest possible level of performance while meeting other constraints. Design exploration provides detailed guidance that helps the engineering team strike the right balance between the many trade-offs in the typical design process. Product quality can be improved by selecting a point in the design space that will be affected to an acceptable degree by manufacturing variation. The ability to move directly to the optimal design reduces time to market and lowers engineering costs.

Design exploration provides detailed guidance that helps the engineering team strike the right balance between the many trade-offs in the typical design process. Optimization technologies enable users to define the design space, identify the relevant design parameters that the design is sensitive to, and optimize the design by adjusting those parameters.

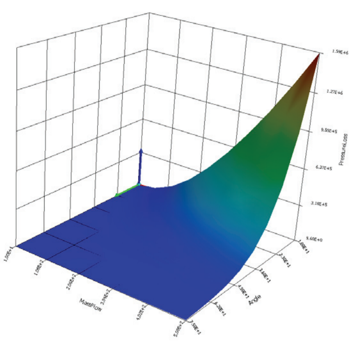
Obstacles to Optimization

Despite all of these enormous potential benefits of optimization, only a relatively small number of companies have integrated optimization into their design process. Engineering simulation software provider ANSYS, Inc. recently surveyed design engineers and found that 63.7 percent of respondents were not using optimization. When asked what the obstacles to optimization were, they replied:

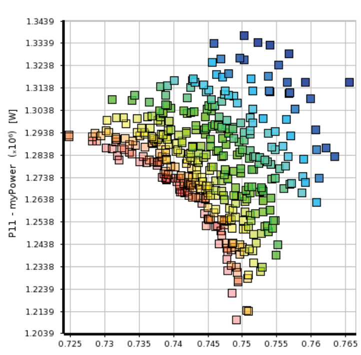
Full series of simulations takes too long	38%
Difficult to build a parametric geometry or mesh	36%
Lack of simulation resources	21%
Difficult to string various tools together	19%
Hard to determine which parameters are relevant	19%
Baseline model is difficult to solve	15%
Lack of faith in simulation	13%
Hard time finding right optimization algorithm	8%



ANSYS CFX® software results show areas of turbulence inside the valve body, indicating areas that could be modified to reduce pressure losses. The contours represent velocity. ANSYS CFD and ANSYS DesignXplorer were used to optimize the design. *Courtesy Cameron.*



This response surface plot shows flow, arm angle and pressure loss data that can be used by engineers to optimize the design of the check valve shown in the above image. *Courtesy Cameron.*



With the help of graphical representation, trade-offs between performance criteria and design criteria can be made.

The largest obstacle to optimization is the amount of time required to run a series of simulations. If one point takes 8 hours to solve, engineers don’t feel that they can wait for 28 or 128 runs.

Another major obstacle is building a parametric geometry or mesh that can be used to iterate automatically through the design space. Most CAD tools today are parametric, providing the ability to adjust the value of a number in the setup without needing to restart from scratch. The problem is that when you update a geometry parameter, it automatically makes everything downstream out of date. If the geometry of your model is parametrically adjusted, then the mesh generated for that model and the solution based on the earlier mesh is no longer valid. The user is forced to regenerate the mesh, pass the files to the solver, set up the solver run again, redo the report, and so on.

ANSYS Helps to Overcome Obstacles

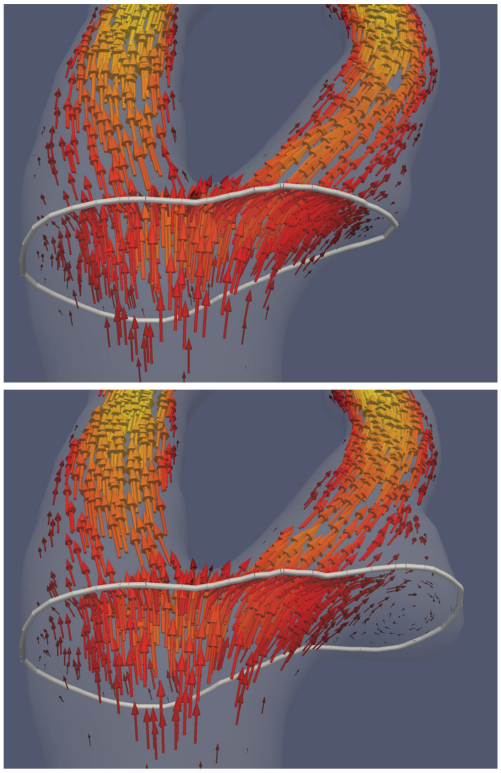
Simulation-Driven Product Development™

ANSYS simulation tools operate in the ANSYS® Workbench™ environment, which makes design optimization a very simple extension of a single simulation. When you change a geometry parameter, ANSYS meshing tools are smart enough to reapply the previous setup, including mesh distributions specific to the changed entities. ANSYS solvers can also re-apply their setup and solve the new model. The post-processor then regenerates all of the images, tables, animations, reports, etc. This enables engineers to easily compare different designs. Parametric persistence makes it possible to automate the optimization process simply by giving Workbench a table of varying parameters and hitting “update.” File transfer, mapping between physics, boundary conditions, etc. remain persistent during the update.

Automating the Simulation Process

ANSYS DesignXplorer™ brings optimization for all physics to the Workbench environment and supports analyses in which multiple physics are coupled or analyzed independently. The multiphysics simulations run automatically without human intervention. The integration platform provides seamless data transfer between applications and a process controller that sequentially simulates all of the design points and collates the outputs. When the user clicks the “update all design points” button, the first design point, with the first set of parameter values, is sent to the parameter manager in the Workbench integration platform. This drives the changes to the model from the CAD system to post-processing. The new design point is simulated and output results are passed to the design point table, where they are stored. The process continues until all design points are solved, defining the design space so that it can later be optimized.

Courtesy Dr. Raffaele Ponzini CILEA, Italy (www.cilea.it), Dr. Luca Antiga, Orobox Srl, Italy (www.orobix.com) and Dr. Marco Evangelos Biancolini, University of Rome Tor Vergata, Italy (www.mec.uniroma2.it).



Thanks to the RBF-Morph solution, researchers can study different clinically relevant anatomical modifications of a carotid bifurcation. Morphing the computational grid to the different carotid bifurcation shapes dramatically speeds up the simulation process.

The adjoint solver indicates what portion of the geometry to modify and how to modify it to obtain the optimized down-force on this Formula One design.

Sampling the Design Space

DesignXplorer features a variety of design of experiment (DOE) types that subdivide the design space to efficiently explore it with a relatively small number of simulation experiments. A response surface can be fit to the results, making it possible to predict the value of every other design point within the design space. The DOE table of design points can be solved in batch mode on your local machine or remotely distributed for a simultaneous solve.

Morphing Makes Geometry Reusable

ANSYS integrates morphing technology within the computational fluid dynamics (CFD) solver to solve a series of design points without having to manually create a new geometry and mesh. Developed with ANSYS software partner RBF Morph, the entire setup can be done within ANSYS Fluent® using a comprehensive interface to define the morphing problem. The engineer defines a series of shape parameters that form the basis of the design space. The computational mesh is morphed for each design point within the active case file, and convergence can continue from the previous solution. There is no need to update the geometry until after the final design is selected.

Gradient Information Determines Which Way to Go

Some applications may have more design variables than are practical to optimize, even with this automated approach. The discrete adjoint solver in ANSYS Fluent performs a sensitivity analysis of output functions with respect to a variety of input parameters, including design shape. The adjoint solver generates sensitivity information on thousands of design variables at the computational cost of a handful of CFD flow simulations. The solver produces 3-D visualization of the results across the surface, showing which direction to go to improve the design. The user can make design changes inside Fluent based on the adjoint sensitivity data. A mesh-morphing algorithm deforms the geometry according to the shape sensitivity field to improve the design.

Graphically Investigate Product Behavior

ANSYS DesignXplorer provides a variety of charts that help engineers visualize the design space and select the optimal design. Response surface plots intuitively show how output variables are dependent on the chosen design parameters. Sensitivity plots show the sensitivity of the performance to the design parameters. Trade-off plots help to identify a range of input parameters that achieve a given goal. Parallel coordinates or Pareto plots provide insights into the maximum achievable design performance and ideal range for each input parameter.

Dyson Case Study

Being named to *Time Magazine*'s list of best gadgets is only one of the many honors received by a unique bladeless fan known as the Dyson Air Multiplier™. Dyson engineers faced the challenge of completely rethinking the design of the household fan without the benefit of previous experience with similar products. They used ANSYS Fluent® software to visualize fluid flow without the need for a physical prototype to gain an intuitive understanding of the design. Dyson's engineers honed in on a few key dimensions as having a major impact on performance and used ANSYS DesignXplorer to investigate more than 200 different design iterations, gaining a 2.5-fold improvement in performance over the original design concept.

Making Sure the Design Doesn't Fail

In the real world, values of manufacturing as well as operational or environmental variables — such as dimensions, loads, boundary conditions and material properties that are assumed to be fixed in simulation — actually vary due to manufacturing tolerances and other factors. DesignXplorer's six sigma analysis uses information about the uncertainty of input parameters to determine the expected output variation. This helps to determine whether or not the design meets robustness requirements. If not, the user can look at the sensitivity plot and other charts to decide which parameters should be adjusted or tightened to obtain the required robustness. This information can also reveal which tolerances can be relaxed without compromising the design.

Conclusion

Faced with increasing competition, companies need to produce higher performing products and deliver them to market in shorter time frames to remain competitive. Simulation-Driven Product Development makes it possible to predict product behavior and determine how products will stand up to a wide range of manufacturing, environmental and operating conditions. ANSYS offers an unparalleled breadth of engineering simulation solutions across a broad range of physics, all integrated into the ANSYS Workbench environment. Design exploration and optimization technologies enable users to define the design space, identify the relevant design parameters that the design is sensitive to, and optimize the design by adjusting those parameters. By utilizing the power of simulation, the engineering team can move quickly to the optimal design. Companies can get the design right the first time and bring better products to market faster and at a lower cost.

ANSYS, Inc.
Southpointe
275 Technology Drive
Canonsburg, PA 15317
U.S.A.

724.746.3304
ansysinfo@ansys.com

Toll Free U.S.A./Canada
1.866.267.9724

Toll Free Mexico
001.866.267.9724

Europe
44.870.010.4456
eu.sales@ansys.com